1992

A comparison of alternative transmission paths for administrative data from afloat units.

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THESIS

A COMPARISON OF
ALTERNATIVE TRANSMISSION PATHS
FOR ADMINISTRATIVE DATA
FROM AFLOAT UNITS

by

Charles A. Worrell
March 1992

Thesis Advisor: Dan C. Boger

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Naval Postgraduate School 6b. OFFICE SYMBOL *(If applicable)* AS	7a. NAME OF MONITORING ORGANIZATION Naval Postgraduate School
6c. ADDRESS *(City, State, and ZIP Code)* Monterey, CA 93943-5000	7b. ADDRESS *(City, State, and ZIP Code)* Monterey, CA 93943-5000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL *(If applicable)*	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS *(City, State, and ZIP Code)*	10. SOURCE OF FUNDING NUMBERS Program Element No / Project No / Task No / Work Unit Accession Number

11. TITLE *(Include Security Classification)*
A COMPARISON OF ALTERNATIVE TRANSMISSION PATHS FOR ADMINISTRATIVE DATA FROM AFLOAT UNITS (UNCLASSIFIED)

12. PERSONAL AUTHOR(S) Worrell, Charles A.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT *(year, month, day)*	15. PAGE COUNT
Master's Thesis	From To	March, 1992	58

16. SUPPLEMENTARY NOTATION
The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

17. COSATI CODES

FIELD	GROUP	SUBGROUP

18. SUBJECT TERMS *(continue on reverse if necessary and identify by block number)*
Administrative message traffic, Naval Communications, INMARSAT

19. ABSTRACT *(continue on reverse if necessary and identify by block number)*

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All three alternatives are based on collecting data on a shipboard microcomputer, compressing it, and transmitting it to a computer bulletin board system ashore where users can download data via commercial telephone lines. The primary difference between the three alternatives is in the transmission medium used. The first uses military satellite channels. The second uses High Frequency Radio. The third uses INMARSAT, a commercial staellite communication system.

All three alternatives are capable of effectively transferring data, but the best all-around performance was achieved with the INMARSAT based system. Further consideration of the variants on the system tested is recommended because the development of cost saving measures may make it highly competitive with current methods.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS REPORT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Dan C. Boger	22b. TELEPHONE *(Include Area code)* (408) 646-2607 22c. OFFICE SYMBOL AS/Bo

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete — SECURITY CLASSIFICATION OF THIS PAGE

Approved for public release; distribution is unlimited.

A Comparison of Alternative Transmission Paths For Administrative Data From Afloat Units

by

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Lieutenant, United States Navy
B.A., University of Pennsylvania, 1985

Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN TELECOMMUNICATIONS SYSTEMS MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
March 1992

Department of Administrative Sciences

ABSTRACT

This thesis considers the problems associated with moving high volumes of administrative data from afloat units to shore commands. It proposes three alternative technologies and compares them on the basis of effectiveness, reliability, ease of use, and cost.

All three alternatives are based on collecting data on a shipboard microcomputer, compressing it, and transmitting it to a computer bulletin board system ashore where users can download data via commercial telephone lines. The primary difference between the three alternatives is in the transmission medium used. The first uses military satellite channels. The second uses High Frequency radio. The third uses INMARSAT, a commercial satellite communication system.

All three alternatives are capable of effectively transferring data, but the best all-around performance was achieved with the INMARSAT-based system. Further consideration of variants on the system tested is recommended because the development of cost saving measures may make it highly competitive with current methods.

C.1

TABLE OF CONTENTS

I. INTRODUCTION 1

A. OBJECTIVE 1

B. ORGANIZATION OF STUDY 1

II. PROBLEMS WITH ADMINISTRATIVE DATA 3

A. TRANSMITTING ADMINISTRATIVE DATA 3

B. VOLUME OF ADMINISTRATIVE DATA 4

C. NEGATIVE EFFECTS OF CURRENT METHODS 5

D. THE ADVANTAGE OF FINDING ALTERNATIVES 6

III. NEAR TERM ALTERNATIVES 8

A. USING EXISTING CHANNELS BETTER 8

1. FLTSATCOM 9

2. HF 10

B. ADVANTAGES 13

C. DRAWBACKS 15

1. FLTSATCOM 15

2. HF 15

D. COSTS 16

1. FLTSATCOM 16

2. HF 18

E. NEAR TERM SUMMARY 19

IV. A MID-RANGE ALTERNATIVE 21
A. LEASING COMMERCIAL SATELLITES 21
B. INMARSAT 22
1. INMARSAT Network Configuration 22
C. INMARSAT APPLICATIONS 24
1. S A L T S 24
2. S D S A 24
3. S R S 25
D. ADMINISTRATIVE DATA AND INMARSAT 26
E. ADVANTAGES 29
F. DRAWBACKS 30
G. COSTS 30
1. Dedicated Channels 31
2. Per Use Fees 32
H. MID-TERM SUMMARY 32

V. ALTERNATIVE COMPARISON 35
A. COMPETITION FOR RESOURCES 35
1. Distinguishing Administrative From Operational 35
a. Classification 36
b. Precedence 36
c. Originator or Addressee 37
2. Where To Draw The Line? 37
B. DEMAND FOR RESOURCES 38
1. Personnel Data 38

C. COMPARING THE CAPACITIES OF ALTERNATIVES . . . 39

1. The Current Method 40

2. FLTSATCOM 40

3. HF 41

4. INMARSAT 41

5. Capacity Summary 42

D. COMPARING THE COSTS OF ALTERNATIVES 42

1. Cost Definitions 43

2. Uncertainty of HF Costs 44

E. IMPLEMENTATION DRAWBACKS 45

1. FLTSATCOM 45

2. INMARSAT 45

VI. CONCLUSIONS AND RECOMMENDATIONS 47

A. CONCLUSIONS 48

B. RECOMMENDATIONS 48

C. AREAS FOR FURTHER RESEARCH 49

LIST OF REFERENCES 50

INITIAL DISTRIBUTION LIST 51

I. INTRODUCTION

Surface ships at sea are responsible for handling and transferring large volumes of administrative data, even under the most demanding operational conditions. The ill effects of this burden on both combat efficiency and the efficiency of the Naval Telecommunication System are numerous. They include reduced personnel efficiency and lengthy delays for both tactical and non-tactical data being transferred ashore.

A. OBJECTIVE

Technologies that can transfer administrative data more efficiently are currently available in the private sector. The objective of this thesis is to compare three candidate technologies that could improve the transfer of data and identify the best one based on reliability, ease of use, and relative cost. Data was derived primarily from studies by the Space and Naval Warfare Systems Command and the Naval Electronic Systems Engineering Center.

B. ORGANIZATION OF STUDY

Chapter II of this study discusses problems associated with current methods of handling administrative data. Chapter III describes two attempts to use existing communication systems to move administrative data more efficiently. Chapter IV describes an alternative that uses commercial satellite

services to transfer data. Chapter V compares the three alternatives in terms of capacity and cost. Lastly Chapter VI presents conclusions and recommends a possible direction for the future.

All of the alternative systems presented are capable of transferring data efficiently, but of the three, the best combination of low relative cost and high performance is achieved with the commercial satellite option described in Chapter IV. The result of this study is a recommendation to consider using commercial satellite services to transfer administrative data ashore on a battle group level.

II. PROBLEMS WITH ADMINISTRATIVE DATA

For the purposes of this analysis, administrative data is considered as information that does not relate directly to the command and control of naval forces at sea. Some administrative data is vital to the effective functioning of naval forces.

Examples of administrative data that must be passed to and from ships while at sea include: supply inventory data, supply requisition data, ship's maintenance and repair data, aircraft maintenance data, ship's budget and financial data, personnel and pay data, medical data, and safety data. (Space and Naval Warfare Systems, April '91, Encl. 2) Within each of these categories, there is a wide range of urgency associated with given pieces of information.

A. TRANSMITTING ADMINISTRATIVE DATA

Ships currently transfer administrative data to commands ashore by a variety of means, usually dictated by the recipients. Some data is sent by mail or courier, often incurring delays as long as one month, which is not always acceptable for some types of data. Some data is sent by naval message where it competes indirectly with higher priority tactical data for communications resources (NAVELEX, Vallejo, December '90, p. 2). The burden of handling these additional

messages reduces the efficiency of tactical communication channels. During times of heavy traffic, these low priority messages can suffer delays as long as five days (Space and Naval Warfare Systems, February '91, p. 1-1).

B. VOLUME OF ADMINISTRATIVE DATA

There are over 33,000 commands ashore that can send messages to a commander at sea (Space and Electronic Warfare, '91, p. 7). The vast majority of them are not involved in tactical command and control issues.

Today, 98% of all ship-to-shore message traffic is sent via satellite networks such as the Fleet Satellite Broadcast and the Common User Digital Information Exchange Subsystem (CUDIXS). In 1990, 54.6% of all traffic on the Fleet Satellite Broadcast and 50.1% of the traffic on CUDIXS was made up of unclassified messages, many of which were no doubt administrative in nature. (Space and Naval Warfare Systems, February '91, p. C-1)

Military satellite channels routinely operate at or near capacity, even during peacetime. During times of crisis when activity is high or MINIMIZE is imposed, tactical and administrative messages alike experience lengthy delays. (Space and Naval Warfare Systems, April '91, Enclosure 2, p. 1)

The evolution of Over The Horizon Targeting brings the need to transfer even more information between ships over

longer distances. This places more demand on already burdened satellite channels and causes longer delays for all users.

C. NEGATIVE EFFECTS OF CURRENT METHODS

Current methods of transferring data are based on a communications architecture that was designed decades ago. Today's users expect a level of service that pushes the limits of the existing communications structure. These structural limitations result in an array of symptoms that appear as inadequacies in distribution, throughput, and speed of service.

Tactical satellite networks are unable to effectively segregate operational traffic from less critical administrative traffic. Messages are separated by their assigned precedence and handled on a first in, first out basis within those categories. In afloat message centers, vital tactical messages on ship's movement or weapons employment are often obscured in a sea of messages on the availability of uniform items or proper storage temperatures for fresh vegetables.

Operation Desert Storm demonstrated that long periods of MINIMIZE can bring non-tactical support activities to a standstill. (Space and Naval Warfare Systems, April '91, p. 1) Thousands of commands ashore that are trying to improve fleet readiness ultimately reduce combat efficiency by inadvertently slowing down the command and control process.

Night intentions messages from the Battle Group Commander are losing the fight against urinalysis test results.

D. THE ADVANTAGE OF FINDING ALTERNATIVES

There are several alternatives to handling administrative data by the current methods; some of them will be described in this thesis. The most visible advantage that would result from most of them is the increased speed with which administrative data would be received ashore. The delays of weeks or days that are currently accepted could be reduced to hours and minutes. This would result in more accurate data bases for the Navy's shore establishment and, hopefully, better service for the forces afloat.

If requisitions were received ashore faster, repair parts might reach ships at sea sooner. If shipyards could receive work orders and technical drawings faster, they might begin planning repairs sooner and be ready to start work as soon as a ship reached port. Better management of administrative information could result in improved fleet readiness. (Space and Naval Warfare Systems, February '91, p. 6-7)

In addition, removing administrative data from over-burdened tactical channels would improve the performance of these channels. The reduced volume would allow existing systems to deliver higher throughput and speed.

Placing only tactical data on tactical channels would also streamline the distribution process, helping users manage

information more efficiently. The liberated capacity would allow satellite channels to accommodate growth in tactical message traffic, due to the advent of over the horizon targetting, without degrading performance.

III. NEAR TERM ALTERNATIVES

The problems caused by transmitting a high volume of administrative data over tactical channels are pressing. A complete and effective solution will take time to design and even longer to implement. The Navy has made efforts on many levels to provide some slight relief at low cost in the near term.

The Bureau of Personnel and the Naval Aviation Support Office have each developed separate systems to try and remove some of their data from conventional Navy channels. The Naval Electronic Systems Engineering Center has experimented with two systems that might help the entire Navy to use conventional channels more efficiently.

A. USING EXISTING CHANNELS BETTER

The Naval Electronic Systems Engineering Center in Vallejo, California (NAVELEX, Vallejo), conducted tests on transferring administrative data in 1990. The tests evaluated alternative uses of both the Fleet Satellite Communications System (FLTSATCOM) and conventional high frequency radio channels (HF). All tests were conducted using standard shipboard equipment and commercial off-the-shelf hardware and software.

Data transferred came from four different computer-based management information systems found aboard ship. There were requisitions and accounting data from the Shipboard Non-tactical Automated Data Processing Program (SNAP). There was pay and personnel data from the Uniform Microcomputer Disbursing System (UMIDS). There was maintenance and repair data from the Maintenance and Repair Management System (MRMS). And there was meteorological data from the Tactical Environmental Support System (TESS).

The FLTSATCOM portion of the test was conducted between USS RANGER (CV-61) and NARDAC San Diego, while the HF portion was conducted between USS FREDERICK (LST-1184) and NARDAC San Diego. In the test, the administrative data was collected on a floppy disk, and rather than being formatted into a hard-copy narrative message, it was loaded onto a dedicated PC and compressed.

1. FLTSATCOM

In the FLTSATCOM portion of the test, the compressed data was electronically transferred to an AN/WSC-3 transceiver through an Advanced Narrow-band Digital Voice Terminal (ANDVT). The ANDVT was used to provide encryption and as an adapter since the output port on the PC was not compatible with the input ports on the AN/WSC-3. The transceiver transmitted the data to NAVCOMTELSTA Stockton via FLTSATCOM where it was received on another AN/WSC-3. Upon receipt, the

data was electronically transferred to a PC through an ANDVT. At the PC, an operator transferred the files to a computer bulletin board system (BBS) at NARDAC San Diego over land-based commercial telephone lines (see Figure 1).

Test files were compressed using a commercial compression software called PKZip which achieves a 70% compression ratio. Data transfers were conducted successfully at 2,400 bits per second. Most test files were limited to not more than 720 characters, although files of 2,182 and 43,000 characters were transferred without error. (NAVELEX, Vallejo, December '90, pp. 16-17)

2. HF

In the HF portion of the test, the compressed data was sent to an HF modem through a KG-84C encryption set and transmitted on an AN/URT-23. NAVCOMTELSTA Stockton received the transmission on an AN/URT-23. The transmission was demodulated with an HF modem and decrypted with a KG-84C. The data was loaded onto a PC that automatically transferred the data to a BBS at NARDAC San Diego via land-based commercial telephone lines (see Figure 2).

Testing was done both inport and at sea at ranges exceeding 800 nautical miles. Test files were compressed by 70% using PKZip and transmitted at 2,400 bits per second. The average file size was 6,343 characters. The equipment automatically aborted the transfer if the channel conditions

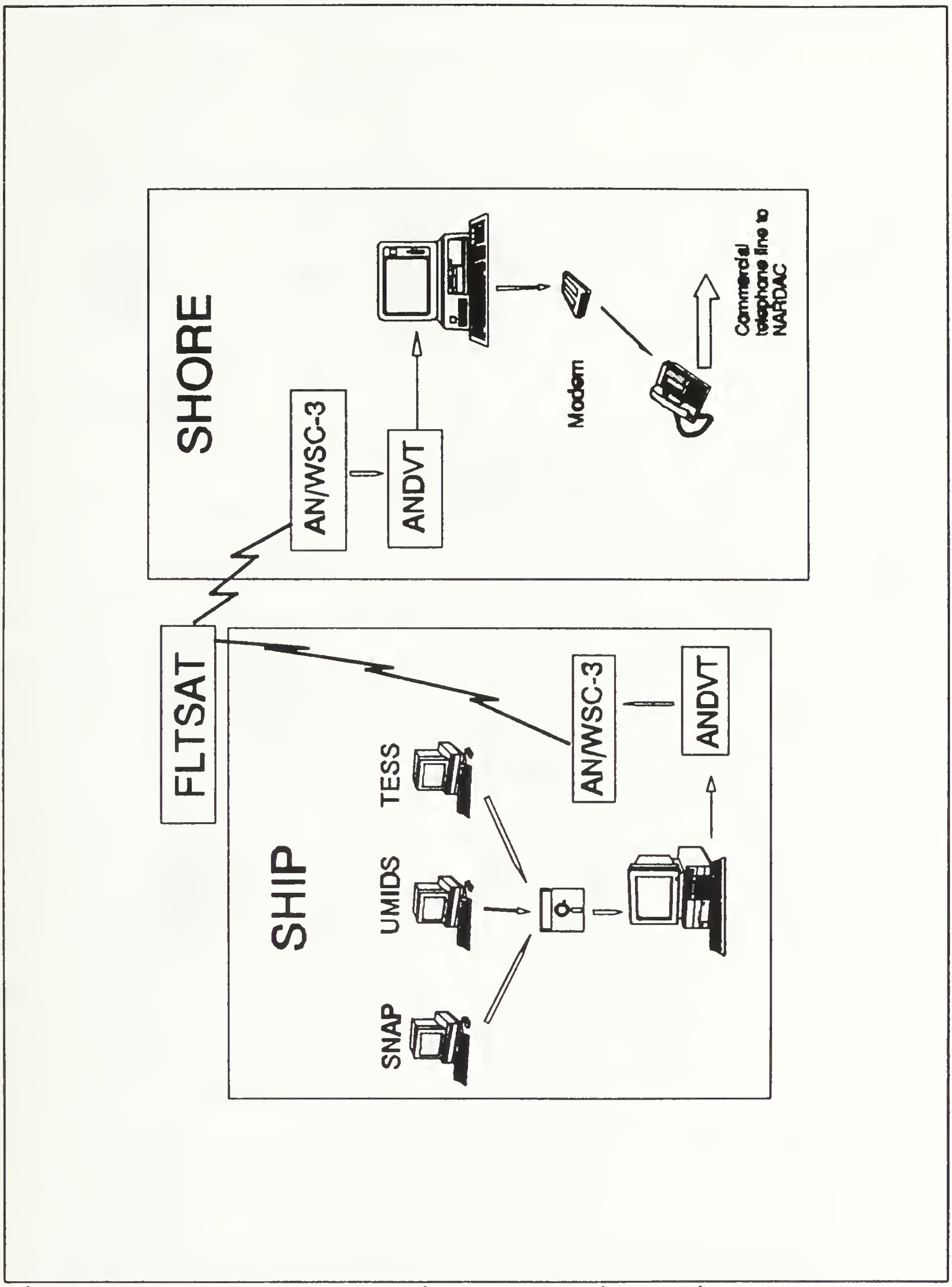

Figure 1: FLTSATCOM equipment configuration. (NAVELEX, Vallejo, December '90, p. 7)

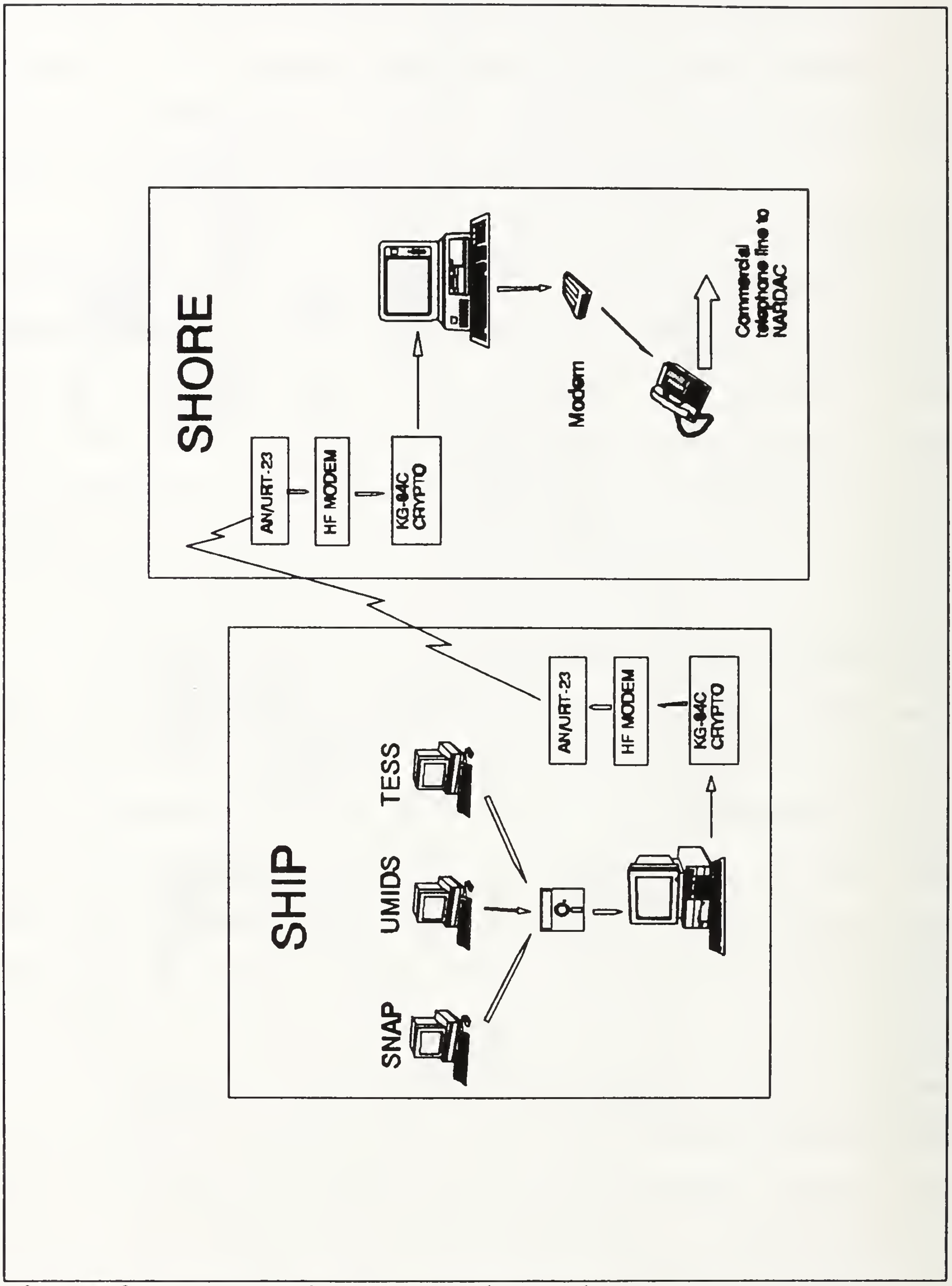

Figure 2: HF equipment configuration. (NAVELEX, Vallejo, December '90, p. 8)

would not support error-free communication; as a result it took 104 attempts to successfully transfer 83 files.

At NARDAC San Diego, the BBS stored the files. Users who needed the data could use a modem to dial up over land-based commercial telephone lines to download the files that they needed (see Figure 3). (NAVELEX, Vallejo, December '90, p. 8)

B. ADVANTAGES

The primary benefit of these two techniques is in simplified message handling both aboard ship and ashore. Rather than producing narrative reports, managers for systems like SNAP or TESS could submit a floppy disk once a day that could be easily and automatically transmitted to a BBS. End users could then download data at their leisure. There would be no need for proofreading, retyping, message sorting, or delivering messages to the end users.

The communication channel (satellite or HF) realizes some relief because the compressed data takes less time to transmit than the uncompressed text. The compression rate is the percent reduction in message length over the uncompressed original. If data is compressed with a 70% compression rate, the compressed data is encoded in 30% as many bits as the original. (NOSC, August '89, pp. 3-5)

Administrative reports would no longer be limited to a narrative format. Since the data is being submitted and

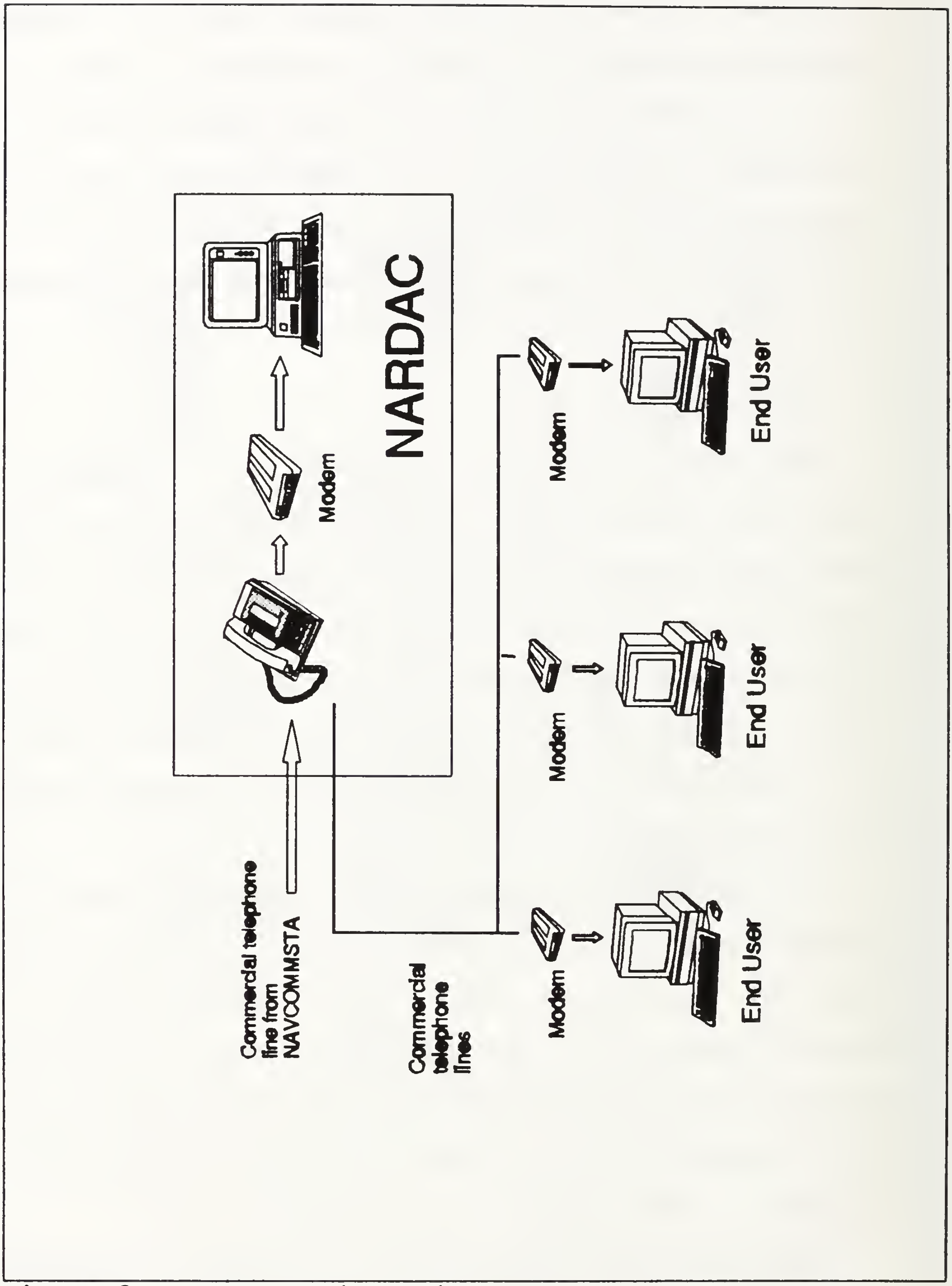

Figure 3: BBS configuration.
(NAVELEX, Vallejo, December '90, p. 9)

transferred as a binary file, graphs and drawings are easily accommodated. This is invaluable when requesting repairs or submitting work packages as with MRMS.

The FLTSATCOM system tested saw no increase in data rate over the traditional FLTSATCOM configuration except as achieved through data compression. However, the HF system tested achieved a substantial increase in data rate from 75 bits per second for traditional HF systems to 2,400 bits per second by using a high speed HF modem.

C. DRAWBACKS

Both systems tested are capable of providing reliable data transfers in a wide range of conditions. However, this was a preliminary attempt and was not without its shortcomings.

1. FLTSATCOM

Satellite channels and shipboard transceivers are in short supply, and this alternative does little to relieve that. This alternative still leaves tactical and non-tactical traffic in indirect competition for the same channels. In addition, no automated switching system exists to interface transmissions received at the NAVCOMTELSTA with land-based commercial telephone networks; this currently requires operator intervention not needed with other alternatives.

2. HF

Shore-based HF receiving sites are often in remote overseas locations and cannot make connections to U.S.

commercial telephone networks that would support data transfers (Space and Naval Warfare Systems, February '91, p. 6-2). Although there has been extensive investment in the infrastructure to support HF communication systems over the years, the possibility exists that the Navy will phase out the use of HF systems in the future (Space and Naval Warfare Systems, February '91, p.6-2). That would make this alternative much less attractive.

D. COSTS

Cost data supplied by the Space and Naval Warfare Systems Command uses the following assumptions:

- Ten year life-cycle for all alternatives.
- All currently owned equipments represent sunk costs and are not considered in this analysis.
- Only the cost of personnel requirements above current levels is considered here.
- Costs include 60 minutes of data transmission every day for each of 300 ships.
- Yearly maintenance costs are estimated at 15% of initial hardware cost. (Space and Naval Warfare Systems, February '91, p. 6-3)

1. FLTSATCOM

Costs for the FLTSATCOM option include providing all 300 ships with access to DAMA channels as well as operation of the necessary facilities ashore. Non-recurring costs ($2,150,000) include the costs of new construction needed to support the alternative. Initial equipment costs

($139,976,000) include the purchase of shipboard equipment required for DAMA access, as well as the computers and software needed aboard ship and ashore. Installation costs ($52,085,000) include the cost of performing shipboard alterations required for new equipment (see Table 1).

TABLE 1

FLTSATCOM Costs

Non-Recurring Cost	$ 2,150,000
Initial Equipment	$ 139,976,000
Installation	$ 52,085,000
Operating Cost	$ 118,854,000
Maintenance	$ 160,350,000
Training	$ 4,205,000
Total	$ 477,620,000

(Space and Naval Warfare Systems, February '91, p. E-2)

Operating costs ($118,854,000) include the cost of additional manning at NAVCOMTELSTAs as well as commercial telephone fees over the ten year life-cycle of the proposed alternative. Additional manning includes one required watchstander for each NAVCOMTELSTA to transfer received

transmissions to commercial telephone networks. Maintenance costs ($160,350,000) are estimated to cover the life-cycle costs for all new hardware purchased. Training costs ($4,205,000) include the life-cycle costs of instructing personnel on operating procedures. Operating, maintenance, and training costs have been discounted using a 6.25% discount rate over the lifetime of the alternative.

2. HF

The costs indicated here do not include the cost of providing all shore receiving sites with data-grade connections to U.S. commercial telephone networks which represents a considerable expense. The only additional equipment considered here is the HF modems that will be required aboard ship as well as at the shore receiving sites. There are no non-recurring costs because no new construction is needed to support this alternative. Initial equipment costs ($11,599,000) include the purchase of HF modems as well as the computers and software needed aboard ship and ashore. Installation costs ($5,010,000) include the cost of performing shipboard alterations required for new equipment.

Operating costs ($45,270,000) include the cost of additional manning ashore as well as commercial telephone fees over the ten year life-cycle of the proposed system. Maintenance costs ($33,225,000) are estimated to cover the life-cycle costs for all new hardware purchased. Training

costs ($4,405,000) include the life-cycle costs of instructing personnel on operating procedures (see Table 2). Operating, maintenance, and training costs were discounted using a 6.25% discount rate over the lifetime of the alternative.

TABLE 2

HF Costs

Non-Recurring Cost	$	0
Initial Equipment	$	11,599,000
Installation	$	5,010,000
Operating Cost	$	45,270,000
Maintenance	$	33,225,000
Training	$	4,405,000
Total	$	99,509,000

(Space and Naval Warfare Systems, February '91, p. G-1)

E. NEAR TERM SUMMARY

Both of the proposed systems described in this chapter use communication channels more efficiently and give users more flexibility. They are innovative attempts to ease the burden of transmitting administrative data. Unfortunately the costs involved and the long lead times required for fleet-wide

implementation are not justified by the minor improvements to message traffic congestion.

IV. A MID-RANGE ALTERNATIVE

Presumably with more time, better solutions can be implemented. An approach that may yield results lies in the use of commercial communication services.

A. LEASING COMMERCIAL SATELLITES

Many private businesses and several government agencies lease channels on commercial satellites to fill some of their communications needs. The Navy has long experience with satellite leasing, having first contracted with the COMSAT Corporation for the Gapfiller system in 1976. There is also an ongoing contract started in 1984 for the Leased Satellite (LEASAT) System.

LEASAT is owned and operated by Hughes Communications Services Incorporated and supports both the Navy and Air Force by transmitting voice and record traffic. LEASAT employs Demand Assigned Multiple Access (DAMA) and supports such vital tactical networks as the Fleet Satellite Broadcast, the Common User Digital Information Exchange Subsystem (CUDIXS), the Officer in Tactical Command Information Exchange Subsystem (OTCIXS), and the Submarine Satellite Information Exchange Subsystem (SSIXS). (NOSC, August '84, p. 74)

B. INMARSAT

INMARSAT (International Maritime Satellite Organization) provides satellite services to nearly 10,000 vessels from 55 different countries. The satellites support direct dial telephone, facsimile, and data communication service to mobile subscribers both ashore and at sea. COMSAT is INMARSAT's U.S. representative and largest shareholder. COMSAT offers telephone, telex, and data communication services to ships, off-shore oil platforms, and land-based mobile users. (COMSAT, March '89, p. 2)

INMARSAT has been the primary communication system for the Military Sealift Command since 1989. Additionally, there are 28 combatant ships in the Navy that are currently INMARSAT equipped; they use the system primarily for direct dial voice telephone service. The list of the Navy's INMARSAT-equipped ships includes 15 CVs, 5 LCCs or other flagships, and 3 tenders or repair ships. (Space and Naval Warfare Systems, February '91, p. B-1)

1. INMARSAT Network Configuration

The INMARSAT network is composed of a ground segment, a space segment, and a shipboard segment. On the ground, COMSAT operates two earth stations that receive the down-link signal from the satellites and establish circuits with land-based commercial telephone, telex and data networks. One

earth station is in Southbury, Connecticut; the other is in Santa Paula, California. (COMSAT, March '89, p. 3)

In space, INMARSAT has a constellation of three satellites in geosynchronous orbit 22,300 miles above the equator. These three satellites have provided world-wide coverage since 1982. They use SHF (Super High Frequency) transceivers and employ circuit switching technology. The system can support 335 channels simultaneously, each with a bandwidth of 3 KHz. By 1995, the organization plans to introduce INMARSAT 2 which will feature a constellation of four improved satellites. The new satellites will increase the speed of the standard data service from 4,800 bits per second to 9,600 bits per second as well as offer expanded customer services. (Space and Naval Warfare Systems, February '91, p. 3-2)

The shipboard segment comes in two variants; the configuration of interest here is the Standard-A system. The Standard-A terminal provides full telephone, data and telex service and has two primary components. The above-deck component is a gyro-stabilized radome that houses the transceiver and an 85 centimeter antenna. The below-deck component houses the terminal itself and associated communications hardware such as dial telephones, modems or facsimile machines. (COMSAT, March '89, p. 3)

C. INMARSAT APPLICATIONS

There are many initiatives already underway in the fleet to apply INMARSAT capabilities to satisfy communication needs. The Naval Aviation Support Office (ASO) in Philadelphia, the Bureau of Personnel (BuPers), and the Navy Broadcast System are all using INMARSAT capabilities to improve their operations. During Operation Desert Storm, many Navy and Marine Corps commands made use of INMARSAT to pass time-sensitive logistics and personnel data while MINIMIZE was imposed. (Naval Supply Systems, April '91, p. 5)

1. S A L T S

ASO Philadelphia developed SALTS (Streamlined Alternative Logistics Transmission System) to allow INMARSAT-equipped ships to send them aircraft maintenance data more efficiently. They used standard, commercially-available hardware and software to transmit data from ships at sea to a computer bulletin board in their offices via INMARSAT.

SALTS normally operates at a data rate of 9,600 bits per second. The whole system was designed in three weeks, and they were able to equip each ship involved with a PC, a modem, and all required software for $ 6,000. (BuPers, May '91, p. 1)

2. S D S A

The Bureau of Personnel is experimenting with SDSA (Source Data System Afloat). It has installed a PC-based

system that can tie the USS Ticonderoga into the Source Data System network using UMIDS or an INMARSAT terminal. The Source Data System (SDS) is a data processing system designed to improve pay and personnel services by automating the maintenance and submission of data to the Navy's pay and personnel databases.

SDS provides automation for 75% to 80% of shipboard personnel office functions including the exchange of information between personnel and disbursing offices. With the exception of USS Ticonderoga, all ships must perform personnel transactions manually and communicate with BuPers either with awkward OCR forms which are sent through the mail or with naval messages. The SDSA experiment has been acknowledged by CINCLANTFLT to reduce message traffic congestion, increase personnel office productivity, and improve the quality of service. (BuPers, April '91, p. A-2)

3. S R S

The Navy Broadcast System (NBS) produces and transmits entertainment programming of the Armed Forces Radio and Television Service (AFRTS). In 1988, NBS stopped transmitting its audio programming via shortwave radio and began transmitting on a downlink channel of the INMARSAT system to improve signal quality. In order to receive these transmissions, ships at sea must be outfitted with a Standard-A terminal which NBS calls a Shipboard Receiving System (SRS).

NBS began installing SRSs in a receive only configuration in 1990. The current plan is to install SRS in 285 ships with subsequent upgrade to a transmit/receive capability under review by the Chief of Naval Operations. (Space and Naval Warfare Systems, February '91, p. I-4)

The SRS program will cause a marked increase in the number of INMARSAT-equipped ships in the fleet. This should significantly decrease the calculated cost of any other INMARSAT-related programs underway.

D. ADMINISTRATIVE DATA AND INMARSAT

In 1990 NAVELEX, Vallejo tested the effectiveness of the INMARSAT system at transferring administrative data. It collected data from SNAP, UMIDS, MRMS and TESS and transferred them to a PC on a floppy disk. The data was then compressed using PKzip and transmitted through the INMARSAT system using a conventional modem and a Standard-A terminal. Upon receipt at the COMSAT ground station, the data was automatically transmitted to a computer bulletin board at NARDAC San Diego via land-based commercial telephone lines. Shore-based commands that needed the data could then dial up and download the files that they needed (see Figure 4). (NAVELEX, Vallejo, December '90, p. 6)

The INMARSAT testing took place onboard USS RANGER, USS LEXINGTON, USS CAPE COD, and USS INDEPENDENCE. Data was routed through the ground stations at both Southbury,

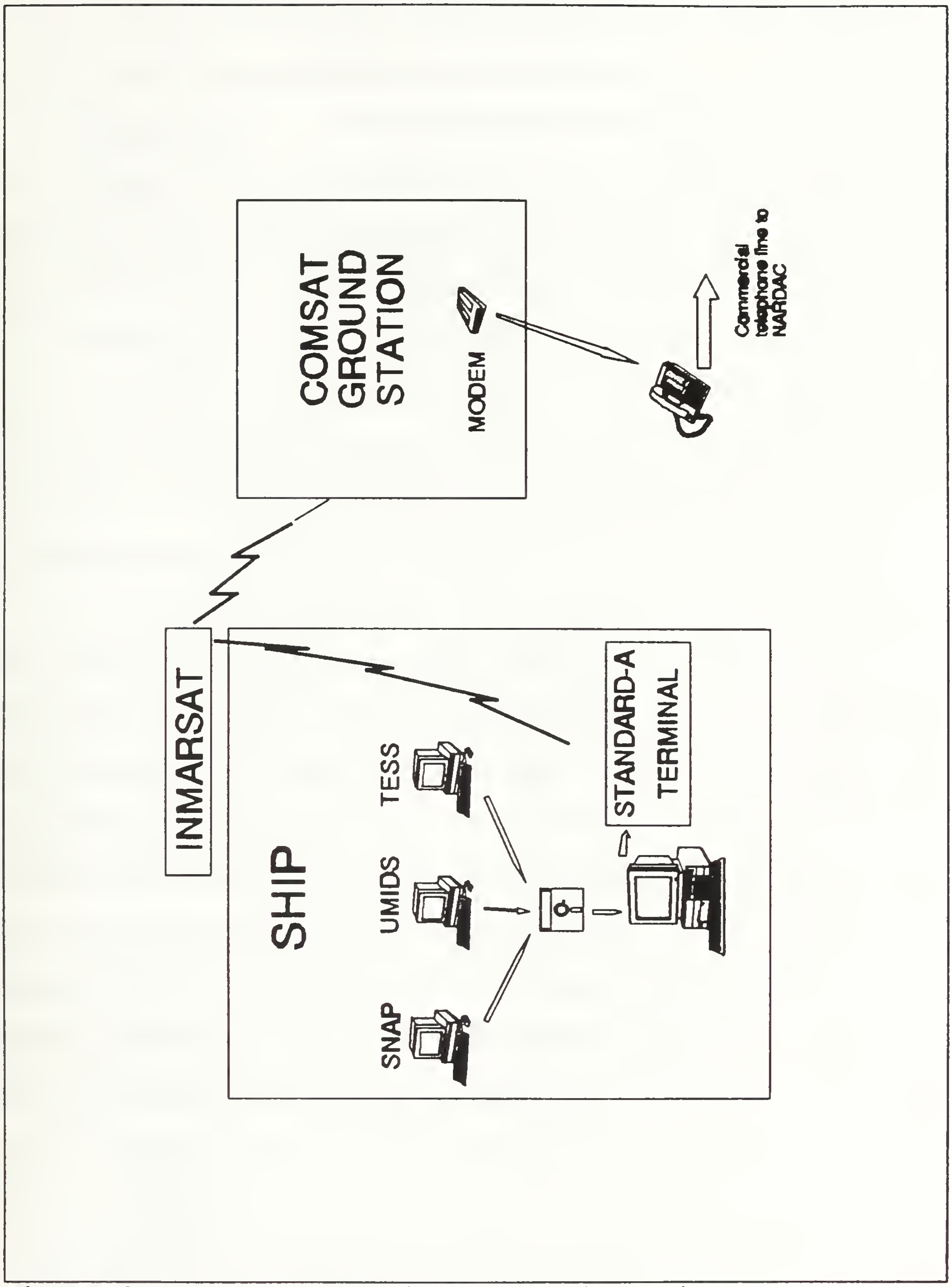

Figure 4: INMARSAT equipment configuration. (NAVELEX, Vallejo, December '90, p. 6)

Connecticut, and Santa Paula, California. A variety of conditions were encountered both inport and at sea. All files sent were received without error.

The average size of the test files before compression was 399 kilobytes while the average file size after compression was 72 kilobytes. The largest file transferred was 7.4 megabytes before compression and 1.3 megabytes after compression. The average throughput achieved was 210 characters per second while transmitting at 2,400 bits per second, 410 characters per second at 4,800 bits per second, and 850 characters per second at 9,600 bits per second (see Table 3).

A total of 1,896 files were sent; 1,714 at 2,400 bits per second, 172 at 4,800 bits per second, and 10 at 9,600 bits per second (see Table 3). A document containing combined text and graphics was transmitted at both 2,400 and 4,800 bits per second. The quality of the received document was equivalent to a facsimile sent over commercial telephone lines and was acceptable to users. All end users reported receiving usable data, although in some cases the format differed from that normally received. (NAVELEX,Vallejo,December '90, pp. 15-16)

TABLE 3

INMARSAT TEST SUMMARY

Transmission Speed	# of Files Sent	Avg. Throughput
2400 bps	1714	210 char. / sec.
4800 bps	172	410 char. / sec.
9600 bps	10	850 char. / sec.

E. ADVANTAGES

The technique utilized by NAVELEX, Vallejo, greatly simplifies the required message handling both aboard ship and ashore. The entire process is automated from the moment the ship transmits the data to the moment that the end user dials in to receive the data.

Perhaps most important, it removes administrative data from tactical circuits. This would free up traditional communication resources for more pressing tactical applications. It would also result in administrative data reaching users more quickly since the data would no longer have to compete with messages of higher precedence or travel through the mail.

Administrative reports would no longer be limited to a narrative format. Since the data is being submitted and

transferred as a binary file, graphs and drawings are easily accommodated. This is invaluable when requesting repairs or submitting work packages as with MRMS.

F. DRAWBACKS

The drawbacks to this option lay mostly in developing effective billing procedures. If individual ships are billed for their rates of usage, they may become less willing to respond to requests for data from shore commands. If shore commands are billed for the cost of transmitting data that they request, accounting procedures may become unwieldy. Lastly, if the Navy leases channels full time, elaborate scheduling procedures would be needed to ensure each ship fair access to the system.

G. COSTS

Cost data supplied by the Space and Naval Warfare Systems Command uses the following assumptions:

- Ten year life-cycle for all alternatives.
- All currently owned equipments represent sunk costs and are not considered in this analysis.
- Only the cost of personnel requirements above current levels is considered here.
- Costs include 60 minutes of data transmission every day for each of 300 ships.
- Yearly maintenance costs are estimated at 15% of initial hardware cost. (Space and Naval Warfare, February '91, p. F-2)

Since the Navy Broadcast System appears to be proceeding with its SRS program, the Standard-A terminals required for each ship in the program are considered as currently owned equipment.

1. Dedicated Channels

This option assumes a lease for full time use of sufficient INMARSAT channel capacity to meet fleet needs. The Naval Space and Warfare Systems Command estimates that the fleet would need 60 minutes per day for each of 300 ships. This figure was arrived at by analyzing current INMARSAT use by combatant ships and extrapolating to account for additional transmission requirements. (Space and Naval Warfare Systems, February '91, p. F-1)

There were no non-recurring costs because no new construction is required to support this alternative. Initial equipment costs ($11,750,000) include the purchase of modems as well as the computers and software needed aboard ship and ashore. Installation costs ($2,230,000) include the cost of performing shipboard alterations required for new equipment.

Operating costs ($48,871,500) include the cost of leasing dedicated satellite channels as well as commercial telephone fees over the ten year life-cycle of the proposed system. Maintenance costs ($27,570,000) are estimated to cover the life-cycle costs for all new hardware purchased. Training costs ($4,050,000) include the life-cycle costs of

instructing personnel on operating procedures (see Table 4). (Space and Naval Warfare, February '91, p. F-2) Operating, maintenance, and training costs have been discounted using a 6.25% discount rate over the lifetime of the alternative.

2. Per Use Fees

This option assumes that the Navy contracts for sufficient INMARSAT channel capacity at a rate of $6.25 per minute. Sufficient capacity is estimated at 18,000 minutes of satellite time each day (60 minutes a day for each of 300 ships). The only difference from the dedicated channel option lies in the increased operating costs of $118,739,744 which change because of the different billing scheme (see Table 5).

H. MID-TERM SUMMARY

The use of INMARSAT to transfer administrative data offers many unique advantages. It removes a large volume of traffic from over-laden tactical channels. It removes the burden of relaying the data from Navy hands entirely. It gives great flexibility to the users of administrative data both afloat and ashore.

TABLE 4

INMARSAT Costs (Dedicated channels)

Non-Recurring Cost	$ 0
Initial Equipment	$ 11,750,000
Installation	$ 2,230,000
Operating Cost	$ 48,871,500
Maintenance	$ 27,570,000
Training	$ 4,050,000
Total	$ 94,471,500

(Space and Naval Warfare Systems, February '91, p. F-2)

NBS will complete SRS installation in 1993, PC and bulletin board installation can be completed in a matter of weeks. With sufficient investment in capital and in new procedures, this option could greatly improve the speed and the quality of service of many administrative commands. Today's technology will allow commercial enterprises, such as COMSAT and INMARSAT, to provide services that have, until recently, been beyond the capability of everyone but the government.

TABLE 5

INMARSAT Costs (Per Use Fees)

Non-Recurring Cost	$ 0
Initial Equipment	$ 11,750,000
Installation	$ 2,230,000
Operating Cost	$ 118,739,744
Maintenance	$ 27,570,000
Training	$ 4,050,000
Total	$ 164,339,744

(Space and Naval Warfare Systems, February '91, p. F-2)

V. ALTERNATIVE COMPARISON

Several alternatives have been presented that attempt to address a complex problem. In order to view the alternatives more clearly, some of the issues mentioned earlier are discussed in more detail below.

A. COMPETITION FOR RESOURCES

As described in Chapter II, from the fleet perspective it is easy to see that operational data is losing the competition with administrative data. The sheer volume of administrative traffic that arrives aboard ship through tactical channels makes it difficult for users to extract the tactical data that they need. Yet, the precise extent of the problem is very difficult to quantify for a number of reasons.

1. Distinguishing Administrative From Operational

Distinguishing administrative traffic from operational traffic can be a formidable task. Until one can distinguish between the two types of messages as they pass through the Naval Telecommunication System (NTS), the extent of the problem cannot be measured. There are several message characteristics that one can analyze, but none yields consistent results.

a. *Classification*

The classification assigned to a message provides a few clues as to its purpose. Many operational messages are classified and many administrative messages are not, but this rule is not without its exceptions.

Mail routing messages and many supply-related messages must include ship scheduling or location information that causes them to be classified. Many operational messages such as engineering or safety information are not classified. The classification of a message does not reliably distinguish administrative from operational data.

b. *Precedence*

The precedence assigned to a message also implies something about the operational nature of its contents. If users adhered strictly to established procedures, analyzing the precedence of messages would yield some indication of how much of the data transferred was actually administrative in nature, but for a variety of reasons users do not.

Perhaps most of all, users inflate the precedence assigned to their messages because of the delays they know the messages will encounter when using the overloaded NTS. Users also inflate the precedence of messages to help meet deadlines that are drawing close. The precedence of a message does not reliably distinguish administrative from operational data.

c. *Originator or Addressee*

Analyzing the originator or addressees of a message offers a rough indication of the nature of a message, but it clearly does not reveal enough. The vast majority of traffic released by Commander Carrier Group Four is probably operational in nature, and the Navy Finance Center rarely receives anything of tactical interest; but there are frequent exceptions to these rules, and conclusions derived by this method could be misleading.

It would also be difficult to consider messages with multiple or information addressees. How would one characterize aircraft safety messages sent to address indicator groups with dozens of addressees from all over the world? The originator or addressee of a message does not reliably distinguish administrative from operational data.

2. Where To Draw The Line?

Analyzing the content of each message could be deceiving without taking time to consider the appropriate context. Is a message concerning the transfer of a service member administrative even if he must be airlifted from a ship at sea on short notice? Does a discussion of handling fresh vegetables become operational if it concerns modifying procedures to speed up the next day's underway replenishment?

The distinction between the administrative and the operational is not clear cut. Because there has been no

historic need to make that distinction, the NTS has not developed an effective mechanism to measure the extent to which administrative messages have overrun our tactical circuits.

B. DEMAND FOR RESOURCES

There is a wide range of shipboard functions that require the transfer of administrative data ashore. Chapter II discussed some of those functions and the varied media they employ. Measuring the demand for NTS assets from all those functions would go beyond the scope of this analysis. The next section considers the demand generated by shipboard personnel functions.

1. Personnel Data

The Bureau of Personnel currently receives reports of required transactions from afloat commands via the Diary Message Reporting System (DMRS). The DMRS requires that BuPers be notified by message for over 50 different events including: arrival or departure from port, reporting or detaching of personnel, personnel qualifying for selected watch-stations, reenlistments or extensions, awarding of non-judicial punishment, and adjusting leave or pay.

Some of these transactions require that additional documents be forwarded by mail. BuPers receives equivalent reports from shore commands electronically via the Source Data System.

For a cruiser-sized ship with 350 personnel aboard, the DMRS may require sending as few as three or as many as seven messages each week. A DMRS message will typically consist of from three to ten lines of text. At eight bits per character and 60 characters per line, DMRS generates as few as 4,320 bits per week and as many as 33,600 bits per week. On average, this ranges from at best 617 bits to a worst case of 4,800 bits per day being transferred ashore by each ship for personnel functions alone.

C. COMPARING THE CAPACITIES OF ALTERNATIVES

It is difficult to make a fair comparison of all the alternatives presented because of their fundamental differences. These differences can create hidden imbalances in the benefits or the costs of an alternative.

There is no way to accurately compute the costs incurred by receiving data in five days through the current method when it could have been received in minutes through INMARSAT. It is very difficult to compute the true cost of sending ship's maintenance data through a combination of media (mail, messenger, NTS) in order to compare it with the cost of sending it through a single electronic medium. There are inherent flaws in directly comparing a dated technology like HF radio, which has a limited future, with a newly mature technology like commercial satellite communications. Without accounting for the error introduced by such direct

comparisons, the capacity of the four alternatives to handle a worst case of 4,800 bits of personnel data per day from each of 450 ships, or 2.16 megabits per day is described below.

1. The Current Method

With the current method (DMRS), a ship at sea would report a transaction via naval message with accompanying documents sent by mail. The message would typically arrive in one or two days with the documents arriving in about two weeks. Although the NTS is capable of accommodating the 2.16 megabits per day, it comes at the cost of increasing delays for all manner of operational and administrative traffic by an undetermined amount.

2. FLTSATCOM

With the FLTSATCOM alternative, a ship at sea would record a transaction as a compressed binary file on a floppy disk and transfer that file to a computer bulletin board ashore via FLTSATCOM and the nearest Naval Communications Station. BuPers could then recover the data as needed.

Because of the need for operator action at the NAVCOMTELSTA to forward the data to the bulletin board, it would take from a few minutes to an hour for the data to reach the bulletin board. If BuPers conducted hourly downloads by phone to collect data from the bulletin board, it would take a maximum of two hours for the transaction to be received. Although FLTSATCOM is capable of handling the 2.16 megabits

per day, even without compression, it would result in undetermined delays for both operational and administrative traffic moving through the NTS.

3. HF

With the HF alternative, a ship at sea would record a transaction as a compressed binary file on a floppy disk and transfer that file to a computer bulletin board ashore via HF radio and the nearest Navy HF receiving site. If BuPers conducted hourly downloads by phone to collect data from the bulletin board, it would take a maximum of one hour for the transaction to be received. Since the HF spectrum is no longer widely used, this alternative could accommodate the transfer of 2.16 megabits per day without causing delays for other traffic.

4. INMARSAT

With the INMARSAT alternative, a ship at sea would record a transaction as a binary file on a floppy disk and transfer it to a computer bulletin board ashore via an INMARSAT satellite and a COMSAT ground station. If BuPers conducted hourly downloads by phone to collect data from the bulletin board, it would take a maximum of one hour for the transaction to be received. The INMARSAT system can easily accommodate the transfer of 2.16 megabits per day.

5. Capacity Summary

It is misleading to directly compare the alternatives, but even at the worst case volume for personnel data of 4,800 bits per day from each of 450 ships, all four alternatives are capable of transferring sufficient data. Use of the FLTSATCOM alternative would perpetuate the delays that currently plague the NTS.

The data compression techniques employed in the FLTSATCOM, HF and INMARSAT alternatives would reduce the actual transmitted bit stream by 70% to 1,440 bits per day for each ship or 648 kilobits per day total. Some of this savings would probably be taken up in replacing information currently transferred by mail in documents.

D. COMPARING THE COSTS OF ALTERNATIVES

It is difficult to compare costs between alternatives for a variety of reasons. In the case of the FLTSATCOM alternative, the costs include the expense of providing ships with the equipment necessary to access DAMA channels that could also be used for tactical applications; but this capability is not supported by other alternatives. With the HF alternative, the required shore-based infrastructure is aging and may not be serviceable beyond the proposed ten year program life-span; this obstacle to life-cycle extension is not faced by the other alternatives.

In order to justify implementing a new method of transferring data in today's fiscal environment, it should be demonstrated that the new method will cost less than the current method. Unfortunately, no one has been able to determine the true cost of the current method. The Navy Computer and Telecommunications Command has never been able to determine the precise cost of sending a naval message (Suchar, February '92), and as mentioned above, there is no way of computing the true cost of delays in the receipt of data. There can be no direct comparison between current costs and proposed costs.

1. Cost Definitions

The cost information used for the FLTSATCOM, HF and INMARSAT options was provided by the Space and Naval Warfare Systems Command. The data contained some ambiguities and was not well documented. The following assumptions were used in interpreting them.

Non-recurring costs reflect the expense of new facilities and buildings constructed to support the alternative. Initial equipment costs reflect the expense of purchasing electronic equipment for installation both aboard ship and at shore facilities. Installation costs reflect the expense of planning and conducting the installation of required electronic equipment. (Space and Naval Warfare Systems, February '91, p. 6-3)

Operating costs include the expenses of operating new electronic equipment in addition to charges for the use of commercial telephone services. Maintenance costs were estimated at 15% of the initial equipment costs for every year of operation. Training costs include the cost of producing and distributing training materials throughout the ten year life-cycle of each alternative (Space and Naval Warfare Systems, February '91, p. 6-3).

Although all federal agencies are required to use a 10% discount rate when estimating costs, operating maintenance and training costs were estimated using a 6.25% discount rate throughout the ten year life-cycle of each alternative. Use of the 10% discount rate would have resulted in noticeably lower costs for all three alternatives.

2. Uncertainty of HF Costs

Many of the Navy's 17 shore HF receiving sites are in remote overseas locations and do not have direct access to data-grade commercial telephone lines (Space and Naval Warfare Systems, February '91, p. 6-2). Providing this data-grade connectivity represents a significant expense that has not been included in the cost estimates described above. These monumental costs and the uncertain future of HF radio in the Navy make the HF alternative unworthy of further consideration.

E. IMPLEMENTATION DRAWBACKS

The two remaining alternatives, FLTSATCOM and INMARSAT, are both effective methods for transferring data. Final implementation of either option requires that their associated drawbacks be overcome.

1. FLTSATCOM

The FLTSATCOM alternative is quite expensive with an estimated total life-cycle cost of $477,620,000 (Space and Naval Warfare Systems, February '91, p. E-2). The major cost contributors to this alternative are the procurement and installation of equipment required to give ships DAMA access. Although this alternative would reduce the delays experienced by some administrative data, there is no getting around the fact that it leaves administrative and operational data competing for access to tactical channels.

In addition, no automated system currently exists to interface transmissions received at the NAVCOMTELSTA with land-based commercial telephone networks. This introduces the errors and expenses associated with maintaining an operator on station, a drawback not presented by the INMARSAT option.

2. INMARSAT

Two options for INMARSAT use were presented and each has a unique primary drawback. The Dedicated Channel option, with a total life-cycle cost of $94,471,500, presented the challenge of devising and maintaining elaborate transmission

schedules. The Per Use Fee option, with a total life-cycle cost of $164,339,744, presented the challenge of devising effective billing procedures.

A solution recommended by the Space and Naval Warfare Systems Command (SPAWARS) as a cost saving measure may also be the solution to these drawbacks. SPAWARS recommended a combination of dedicated channels and per use fees to ensure sufficient capacity while minimizing costs (Space and Naval Warfare Systems Command, February '91, p. 6-7).

This combination also yields certain logistic advantages. With the availability of dedicated channels paid for by the fleet commander, a simple transmission schedule that is less than perfect could be implemented. Ships that were unable to complete the transfer of their required data during their allotted time-frame would then be able to transmit at their convenience and pay only for the small amount of additional air time that they needed. This method combines the simplified billing scheme of full time dedicated channels with the flexibility of per use fees.

By combining the two INMARSAT options, all major drawbacks to this alternative could be overcome. INMARSAT can reduce the load on burdened tactical circuits at a relatively low cost while providing vastly improved service to users of administrative data.

VI. CONCLUSIONS AND RECOMMENDATIONS

In the long-term, there are several alternatives that could ease the administrative data burden. Increased use of mail offers some relief as would more aggressive Navy-wide paperwork reduction programs. The COPERNICUS Architecture, a plan to move naval communications into the twenty first century, will also bring some relief.

COPERNICUS will alleviate the administrative data problem by throttling and tailoring the stream of information ashore at the Fleet Commander-in-Chief level. It will move data more efficiently Navy-wide by granting users access to all channels and media whether they be terrestrial, satellite, or commercial. Communications resources will be allocated based on availability, traffic-loading, and precedence, rather than being dedicated according to function as they are now.

Some of the technologies explored in this analysis can be applied to improve the Navy's current communications architecture, and also be integrated into the COPERNICUS architecture. Although all of the technologies presented are capable of reliably transferring administrative data ashore, some conclusions can be drawn.

A. CONCLUSIONS

The following conclusions on the relative merits of the alternatives presented are drawn from the information presented in this study.

- Current methods of handling administrative data present a variety of drawbacks that can be overcome by current technology and that will be unacceptable in the future.

- The FLTSATCOM alternative discussed above is capable of transferring data efficiently, but it does little to ease the burden on tactical communication channels, and its cost is too high in comparison with the other alternatives presented.

- The HF alternative discussed above is capable of transferring data efficiently, but may require extensive additional costs in some locations to provide connectivity ashore with commercial telephone networks; that makes this alternative undesireable.

- The INMARSAT alternative discussed above is the best alternative presented. It is capable of transferring data efficiently, it can be implemented quickly, and its costs are low relative to other options; but budgetary constraints may make even this alternative infeasible.

B. RECOMMENDATIONS

Implementation of the INMARSAT alternative would provide greatly improved logistic and personnel support to the fleet. It could open the door to innovative developments such as paperless ships and moving all administrative functions and personnel ashore.

Use of INMARSAT deserves further consideration in spite of its costs. With proper study, cost reducing measures such as collecting data for transfer within a Battle Group via

cellular phone systems, and then forwarding ashore by one ship may provide the savings necessary to make this system affordable.

C. AREAS FOR FURTHER RESEARCH

Further research to determine the precise costs of sending naval messages and of delays in receiving data ashore would be of great value. This cost information would facilitate careful analysis of the relative benefits of devising alternate methods for transferring data.

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A comparison of alternative transmission paths for administrative data from afloat units.